Analysis of Shoreline Classification and Bio-Physical Data for Carr Inlet

EXECUTIVE SUMMARY

This report summarizes the results of a project (FY97-078) performed for the Dept. of Natural Resources that was designed to test the feasibility and power of a method of classifying the shorelines of Puget Sound, and linking geophysical features of the beaches to the biota therein. A major purpose of the model is to be able to predict differences among the flora and fauna found in the different beach types (mostly soft-sediment) present in the Sound. The project's goals were to: 1) provide a test-case for a new methodology to aid in DNR's current shoreline inventory efforts; 2) help define ways to choose "reference sites" for PSAMP monitoring efforts; 3) begin to quantify what and how many habitat types are present in Puget Sound shorelines; and 4) determine how similar are the biotic elements within and among habitat types.

The 'health' of Puget Sound can have many definitions, including physical, chemical, and biological characteristics. Because biotic features may respond rapidly and sensitively to changes in the other two types, these may provide a useful indicator of overall health. However, the extensive and complex nature of the shorelines of Puget Sound mean that it is unrealistic to monitor the biota in all regions. In addition, monitoring change in biota encounters two fundamental problems. The first is the large variation through time in abundances of organisms in natural ecosystems, which masks our ability to statistically separate an actual change caused by a perturbation (the signal) from natural cycles (the noise). Many monitoring and impact-detection programs have run afoul of the problem of confounding spatial and temporal variation, i.e. of assuming that change has occurred at an impacted site because it is different from a control site, when really the sites were not adequately matched to begin with. Second, if monitoring is done at selected reference sites, we cannot necessarily extrapolate or generalize the results to broad areas. Yet such extrapolation is critical as we try to make predictions about impacts of large-scale environmental phenomena.

One solution to both these problems in the marine realm is to systematically quantify and eliminate physical gradients among sample sites. Minimizing gradients in the physical environment can enhance our ability to detect change, because variation in the environment results in variation in the biota (Schoch & Dethier, 1996). If organisms in Puget Sound are ecologically linked with their physical habitats, then it should be possible to extrapolate results from a few biotic surveys to similar habitats elsewhere.

We describe here the application of a model (Shoreline Classification and Landscape Extrapolation: SCALE) that involves dividing a shoreline into segments of decreasing size and thus increasing geophysical homogeneity. The smallest unit is the alongshore beach segment, which encompasses three

regions (polygons) representing different intertidal elevations. Physically similar polygons are grouped together by statistical clustering techniques, and from these groups a random selection is sampled for biota. We then test each sampled beach segment for community-level homogeneity, i.e. biotic similarity among the replicate samples. If within-segment biota is homogeneous, then physically similar segments are compared for within-group homogeneity. If segments within a group are biologically similar, then inferences can be made about the biota in other segments sharing the physical features of that group. Likewise, if the biota at larger spatial scales (e.g., in one habitat type across several inlets) can be shown to be homogeneous, then extrapolation to similar (but unsampled) beaches is possible. In this way, by linking geophysical attributes of ecological importance to the associated biota, we can make inferences about communities over large areas of shoreline, whereas actual biological sampling will always be more labor intensive and therefore limited in spatial extent.

The site selected for this study was Carr Inlet (including Henderson Bay), the first major embayment south of the Tacoma Narrows (South Sound District). Carr Inlet was first divided into 100 - 1,000 m segments based on principal shoreline substrate characteristics, using low altitude color infrared (CIR) aerial photography. Geophysically homogeneous alongshore segments (10-100 meters in length) were then identified and delineated on orthophoto basemaps while walking the intertidal zone. This partitioning resulted in 310 alongshore segments that could be grouped into 4 spatial blocks corresponding to 4 quadrants of Carr Inlet (varying in wave energy, temperature, and salinity).

Epiflora and fauna (in quadrats), and infauna abundances (in cores) were sampled at 3 sand, 3 mud and 3 gravel beach segments in each of 3 intertidal zones in one spatial quadrant, and additional data were taken at 6 sand, 3 mud and 2 gravel segments in only the lower zone from the three remaining quadrants. The upper and middle zones for both the 'sand' and 'gravel' shoreline segments were characterized by cobbles and pebbles, usually with interstitial sand or with underlying hardpan. The lower zones tended to be characterized by less mixed substrates, e.g. sand or mud (although the 'gravel' shores were still a mix of cobbles, gravel, and sand or mud). A total of 840 quadrats and cores were sampled, with a total richness of 114 taxa (mostly identified to the species-level).

We used multivariate analyses to evaluate the relative homogeneity of communities within and among clusters of beach segments following two types of data transformations. "Indicator values" were calculated for each species, combining information on frequency and abundance in a particular group of samples. Matrices of indicator values for each tide level were analyzed to determine the organisms consistently driving the differences among segments and among groups.

The multivariate analyses clearly illustrate that for Carr Inlet, it is possible to divide and classify intertidal shorelines such that geophysical homogeneity is minimized within a given segment of the shore, and that with this geophysical homogeneity comes relative biological homogeneity. Reducing physical and chemical differences among sites reduces the environmental variation that inevitably results in biotic variation. At larger spatial scales (e.g., different sides of the inlet), biotic similarity within each habitat type (e.g., sand) decreases, as expected, because at these scales there are greater differences in geophysical features such as energy and salinity.

The organism-environment link we were testing is perhaps best seen in the cases where the infauna did not "match" the habitat type as we had classified it; in several cases, errors in beach classification were 'pointed out to us' by the organisms. For example, based on the fauna in the other members of one group of mud segments, we predicted that mud segment 194 should not have sand dollars but it did, probably because of the relatively high proportion of subsurface sand there. Future mapping efforts will be careful to note such subsurface sediment and also seepage characteristics, which were not in the original model.

A variety of species (both infauna and epiflora and fauna) were found to have large indicator values, i.e. had either even abundances or high frequencies in a given set of samples. These species potentially can help to detect change and extrapolate biotic data because they are important to a given habitat type (e.g., mud vs. sand); they can be predictably found in a given substrate type or region, so that their absence would be indicative of unusual conditions. We also used nested ANOVAS to analyze the spatial scales at which each indicator species was most variable, and were able to pick out the taxa that would be best at detecting change at any given scale.

Sixteen older surveys from other Districts of Puget Sound were compared to the data from Carr Inlet. Some habitat types (e.g., the mixed-coarse 'gravel' habitats) had moderate biotic consistency among surveys, whereas others (especially the sand and the mud) were very different. By resampling some of these old sites, both geophysically and biotically, using our methodology, valuable information could be gained about how much of the variation between the old surveys elsewhere in Puget Sound and ours in Carr Inlet might be due to temporal changes, regional differences, or methodological differences.

CONCLUSIONS

Our work in Carr Inlet constitutes the first significant test of a model and methodology that we believe can provide a relatively low-cost, low-tech, *high-resolution* way to quantify the state of Puget Sound shoreline habitats as they are today. Overall, we found a strong relationship between geophysical features and biota, and through extrapolation can predict with reasonable accuracy what organisms (and in what abundances) should be found in beaches in Carr Inlet that we did not sample.

With some further testing, this methodology should be useful for comparing communities in clearly degraded areas versus relatively pristine ones, and for detecting change into the future.

Data from old surveys and anecdotal information indicate that the model cannot yet be extrapolated to areas outside of Carr Inlet; extrapolation will be valid only to similar beaches within a given region. However, the basic methodology we have described should be able to be applied at these larger scales.

Any attempt to scale up biotic data (whether from a beach to the inlet, or from the inlet to the Sound) will involve adding new sources of variation. At some point in this scaling process, the communities in 'similar' beaches are likely to become so different (e.g., as one moves into a different oceanic mixing regime or biogeographic province) that comparisons are not meaningful.

Future decisions about monitoring programs need to be question-driven, with the questions specifying the scale of resolution needed (and thus the scale of variation that must be accepted). Regions, habitat types, and species of particular concern need to be identified by the potential users of monitoring programs.

We recommend that an effort be made to obtain maps of the whole Sound generated by the Harper methodology, and that these be used as a basis for choosing regions and substrate types for further research.

Reference sites need to be chosen on a finer spatial scale, and should be matched geophysically, either with each other or with degraded sites under study. Concentrating research in the low intertidal zone may provide the most information per unit cost in terms of the biota at this level being diverse, productive, and vulnerable to stressors from land and sea. Sampling methodologies need to be consistent among sites, and must include large enough sample sizes to deal with the high natural spatial variability within a site.

In contrast with other, lower-resolution shoreline mapping methods, potential applications of the SCALE methodology and resulting maps include: 1) selecting matched sites for field research or applied monitoring programs; 2) denoting sensitive habitats, e.g. to oil spills; 3) predicting resource-rich habitats, or those where key resource species could exist; 4) assessing biotic damage following unnatural events; 5) choosing areas for conservation efforts; and 6) improving change detection by choosing sites where much of the environmental variation has been factored out.

Only the executive summary is available on the web. Contact the Nearshore Habitat Program for a copy of the entire report.